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## **ABSTRACT:**

The original objective of the SIO Marine Attack project was to identify the electric and magnetic fields causing sharks to inflict serious damage upon the towed hydrophone arrays of US Navy submarines. In contrast to the geophysical arrays that we studied concurrently, the US Navy's arrays appeared to be electromagnetically very quiet by proper design. The only galvanic fields we measured were those of some set screws of a dissimilar metal than the seawater-exposed titanium parts and those of the titanium parts themselves, especially when scratched or abrades during employment. Those fields will evoke bites from sharks coming close to their sources, as we proved in behavioral experiments. Much more serious fields are the image fields of the arrays in the electric fields due to oceanic and ionospheric circulations. As the latter fields can not be removed, we have added to the original project the innovative objective of designing weak counter fields to divert or utterly confuse sharks coming near the arrays. Further studies in our Electromagnetic Research Facility and tests at sea to determine the efficacy of the counter fields are in progress.

This project was originally a three-year project that was to be funded by NAVSEA via ONR and Schlumberger/WesternGeco. The first two years of this project were funded under ONR N00014-00-1-0777 and the last year is currently funded under ONR N00014-02-1-0812.

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# **Marine Attack at Towed Hydrophone Arrays, Final Report**

Project period of 5/15/00 - 2/28/02

by Dr. Ad. J. Kalmijn, Principal Investigator

## **Objectives met during first two years of three-year effort**

- To identify the electric and magnetic fields produced by the towed hydrophone arrays of US Navy submarines, by physical measurement in our research facility.
- To determine the propensity of the measured array fields to attract sharks and cause them to bite the arrays, in behavioral experiments on captive sharks.
- To recommend engineering means and measures to remove the sources of the offending electric and magnetic fields produced by the arrays.
- To design, by use of our computer multipole approach algorithm, weak-electric counter fields to divert or utterly confusing the animals.

## **Objectives to be met during third year of our three-year effort**

Though technically this is a Final Report over the first two years of our three-year effort, the project will continue for a third year as understood from the start.

- To study the linear-dipole image fields that the hydrophone arrays produce in the oceans' environmental electric fields, by physical measurement in our facility, partially done.
- To determine their propensity of soliciting shark bite as a function of the ambient field strength and the diameter of the arrays, a good start made already.
- To determine the analogous hydrodynamic image fields of the arrays when slanted in the water when towed, theoretically predicted and behaviorally observed.

## **Recommendations for further work to complete current effort**

- It is strongly recommended, actually strictly necessary, to test the efficacy of the counter fields in experiments at sea. We have already received the ok to explore the feasibility of such work in the Sea of Cortez, which we successfully did.

## **In summary**

The project as conducted thus far has met, and even exceeded, the original expectations of success. Given the opportunity of bringing the project to completion, we expect to pay our dues worth many times the costs of repair and idle time that we will spare the Navy, and to prevent potential disaster as for the submarines and their crews during critical missions.

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